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From energy to (soil organic) matter

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This work proposes a new view of soil organic matter (SOM) formation: microorganisms use most of the organics entering the soil as energy rather than as a source of carbon (C), while SOM accumulates as a residual by-product because the microbial energy investment in its decomposition exceeds the energy gain. Considering the annual sequestration of C from litter into SOM of 0.4-5% of the total SOM pool, the energy input is equivalent to 1-10% of the total energy of SOM. Thus, more than 90% of the energy added to the soil by plants is lost in microbial transformation, with SOM representing the residual fraction. The conversion of plant litter accumulates approximately ~ 2% of the energy per unit of persisting plant organic matter. This is the proportion of biochemically stable litter-derived compounds and microbial necromass that get accumulated, while oxidized compounds are completely decomposed or recycled. As a result, SOM has more energy per unit C than plant residues, but the availability of that energy is low. This is because SOM composition is more diverse with a non-regular structure compared to plant residues and thus requires a wider range of enzymes to break it down.

The microbial transformation of plant residues into SOM is a never-ending continuum governed by processes such as mineralization, recycling, microbial necromass, and residue accumulation, all of which determine the energy content, fluxes, and nominal oxidation state of C (NOSC) values of the residual litter and the resulting SOM. NOSC and energy content of SOM are narrower in range than litter, with an average NOSC of -0.3, and a higher energy per unit C. Meanwhile, the NOSC values of available compounds (mainly low molecular weight) released from decomposed polymers play a role in the partition of C between catabolism and anabolism in microorganisms. They also affect the energy investment of microorganisms in nutrient mining from SOM.

The conversion of rhizodeposits and plant litter, considered to be the main sources of C in soil, therefore needs to be re-examined from an energy perspective, including energy quality and availability. This would also require the assessment of energy loss and conservation, as almost all microbial processing is directed towards energy acquisition rather than actual C demand. The small amount of plant-derived C and energy that persist in the form of SOM is only an intermediate phase to ensure energy fluxes in the soil system. Thus, the transformation of rhizodeposits and plant litter represents a process of utilization of the energy stored in them, while SOM is the residual material that persists because its microbial utilization is energetically inefficient.